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November 4, 2002

Robert Burns, Esquire
Electric Research
National Regulatory Research Institute (NRRI)
The Ohio State University
1080 Carmack Road
Columbus, Ohio 43210

Tel: 614.292.9404
Fax: 614.292.7196

Subject: Letter Report - New Jersey Stray Voltage/Ground Current Investigation & Final Assessment

Dear Mr. Burns:

VitaTech was recently tasked by NRRI to investigate reported "stray voltage" problems in a neighborhood adjacent to the Herbertsville Substation operated by Jersey Central Power & Light (JCP&L) in the Town of Brick, New Jersey. The objectives of this letter report, which is not a detailed engineering study, are to present the salient information obtained from VitaTech's investigation and to offer a final assessment with recommendations to mitigate the "stray voltage" problem in the Brick neighborhood and nearby Herbertsville Substation.

Initial Meeting & Technical Documentation

Work commenced with a meeting Wednesday morning, 9 October 2002, in the JCP&L Central Division headquarters at 512 Main Street in Allenhurst, N.J. The following participants attended the meeting (please excuse any omitted names):

JCP&L
Mike Ryhal-Director of Operation Services
Bob Kehler-Manager, Regional Engineering
Raquel Mercado-Puchik, Supervisor-Regional Engineering
Bechara Abd, Engineer Senior - Regional Engineering-Distribution
Rich Bashfield, Engineer, Regional Engineering
Michael Obremski, Advanced Business Analyst

State of New Jersey Board of Public Utilities
Riaz Shaikh, Supervising Engineer, Division of Energy

VitaTech Engineering, LLC
Louis Vitale, President & Chief Engineer

JCP&L began by expressing their sincere appreciation for our assistance and offered "full disclosure and cooperation" throughout the project to expedite a timely conclusion. Various technical documents were provided (i.e., substation single line diagram, substation grounding plan, system maps, test data, etc.) including a detailed JCP&L project history*, "Herbertsville – Neutral-to-Earth Investigation"* (see appendix) and list of "stray voltage" complaints. The following week JCP&L delivered the following requested information listed below:

1) Geological report of soil conditions, water tables and wells within a 2000 ft. radius of the Herbertsville substation including a deep well in Frede Park from the State of New Jersey, Department of Environmental Protection dated 24 September 2002;
2) Canadian consultant's report - substation grounding, neutrals, grid resistance, etc.,
3) Harmonic currents and voltages of Lines 82 and 83 recorded on 18 September 2002.

Requested Information Summaries

The State of New Jersey, Department of Environmental Protection performed a Land Use Management Geological Survey as requested by JCP& L and issued a letter dated 24 September 2002. Borings were performed at four sites (Oak Knoll Drive, Driscoll Drive, McArthur Drive and Polk Drive) and "showed uniform geology in the area of concern….fine to coarse quartz sand with quartz-pebble gravel of the Cape May Formation was the uppermost deposit in all the borings". The water table (zone of saturation) was 5 ft. in boring 1, 4.5 feet in boring 2, 11 ft. in borings 3 and 4. There are also 40 irrigation wells ranging from 30 to 50 feet deep within 2000 feet of the Herbertsville substation and a deep well (172 ft.) in Frede Park with fine-to-coarse sand from 0 to 91 feet. Finally, the NJGS measured the soil resistivity at boring #3 (McArthur Drive): from top to 10 feet it was 3000 to 2000 ohm-meters and at 11 feet in the saturated zone (water table) it was 300-ohm-meter.

According to the Canadian Consultant's preliminary report (site work performed around 26 September 2002), "the ground grid within the substation is in good condition", however, the West fence does not appear to be bonded. Only circuit 57383 neutral was "not definitely proven OK due to interference". The substation ground resistances at 620 ft (the 62% of 1000 ft.) were 0.45 ohms (2 ft. ground stake) and 0.65 ohms (1 ft. ground stake) with the LEM GeoX and 0.32 ohms using the AVO/Biddle (Kinectrics) with a 1 ft. ground stake. The substation ground resistance is less than 1 ohm, which is rather acceptable in these sandy soil conditions.

On 18 September 2002 the Spectral Analysis Tool at the Herberstville substation generated an harmonic analysis as a percentage of the 60 Hz fundamental for Lines 82 and 83 -- only the 3^{rd} and 9^{th} harmonics are shown below (note – neutral voltage not recorded):

	Current %		Voltage %			Current %		Voltage %	
Line 82	3^{rd}	9^{th}	3^{rd}	9^{th}	Line 83	3^{rd}	9^{th}	3^{rd}	9^{th}
Phase A	7.1	2.2	0.8	0.2	Phase A	6.5	0.8	0.8	0.2
Phase B	8.3	2.4	0.6	0.2	Phase B	6.8	0.9	0.7	0.2
Phase C	8.4	2.3	0.7	0.2	Phase C	6.5	0.6	0.6	0.2
Neutral	**132.6**	**38**	----	----	Neutral	**79.4**	**8.9**	**----**	**----**

The high triplan (3^{rd}, 9^{th}, 15^{th} etc.) harmonic content on the neutrals, especially line 82, is indicative of excessive zero-sequence currents due to unbalanced phase loads.

Herbertsville Substation & Overview
Two overhead 34.5 kV sub-transmission lines supply two delta-wye transformers in the Herbertsville substation as shown in *Figure #1, Herbertsville Substation Single Line Diagram*. Bank #1 is a pad-mounted 25 MVA transformer (34.5 kV-12.5 kV) connected via a sealed busway to an enclosed switchgear supplying circuits 82 and 83. Bank #2 is a pad-mounted 20 MVA transformer (34.5 kV-12.5 kV) connected via three exposed phases to insulated taps of an enclosed switchgear supplying circuits 80 and 81. Before April 2002, Bank 1 and circuits 82 and 83 were a delta 4.8 kV distribution system (6.25 MVA) until upgraded to a 12.5 kV wye system. *The primary feeder circuits (Lines 80, 81, 82 and 83) use 397AA conductors from the riser poles out through each distribution circuit; however, the primary neutrals vary from 4CU to 2ACSR as indicated on the system drawings.*

The initial "stray voltage" complaint was received by JCP&L on 22 July 2002. Several residents on Driscol Drive and Frede Drive noticed a "tingling sensation" when in contact with pools, Jacuzzis and other conductive objects while grounded to an "earth potential" in their yards and homes. Stray voltage problems were first noticed during the peak summer load when the two transformers and four distribution circuits (Lines 80, 81, 82 and 83) were operating at significantly higher seasonal loads (at least 2 times the average spring, winter and fall loads), after Lines 82 and 83 were upgraded from a delta to wye system in April 2002 and during a very severe drought classified as a D4 in New Jersey (see below) by the U.S. Drought Monitor (http://www.drought.unl.edu/dm/monitor.html):

D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; exceptional fire risk; shortages of water in reservoirs, streams, and wells, creating water emergencies

Measured neutral-to-earth voltages (NEV) were 8-10 volts (and perhaps higher) at pole down-grounds on Driscol Drive, Frede Drive, the 83 riser pole and other circuit locations. Similar voltages were measured from the earth-to-metal pipes, neutrals and grounding conductors inside homes on Driscol and Frede by local electricians with the power (not the neutrals) disconnected. JCP&L immediately responded after the first customer complaint and implemented a "standard troubleshooting procedure" to repair broken neutrals and inspect the system. As the magnitude of the "stray voltage" problem became more apparent, JCP&L implemented a very vigorous mitigation program (see appendix for details) as follows: 1) installed 7,000 feet of 2/0 primary neutral wire (known a reconductoring) from Riser 82 along Spiral Drive to Burnt Tavern Road plus Driscol Drive and McArthur Drive; 2) installed additional down-grounds and rods; 3) re-crimped all transformer connections, and, 4) drove three 40-ft ground rods at terminus locations of Line 82 (Herbertsville Rd and Main Avenue) and Line 83 (Route 80 & Bridge Avenue).

The three actions reduced the neutral-to-earth voltages (NEV) on the down-grounds from 10 V to 5 V on Driscol Drive, Spiral Drive and McArthur Drive and Riser 82. On several occasions VitaTech recorded neutral-to-earth voltages (NEV) around Driscol Drive and other locations around the system as shown in *Figure #5, Neighborhood Neutral-To-Earth (NEV) Voltages & Harmonics*. It should be noted that higher NEV levels (4-8 Volts) remained along Line 83 from the riser pole, along the east service road, south on Oak Knoll Drive to the intersection of Frede and west on Taft Avenue and beyond. The NEV levels (and stray voltage problems) at the down-grounds of Lines 80, 81, 82 and 83 and the substation grid will proportionally increase with the seasonal current loads and changes in soil resistivity (simply stated - the dryer the soil the higher the NEV problem). Therefore, next summer the stray current problems will reappear, especially if there is another drought (the severity is dependant on the weather and soil conditions) unless the primary neutral conductors are upgraded (increased wire size) to be equal to the 397AA phases as shown in *Figure #12, Recommended Upgrade To Primary Neutrals.*

Stray Voltage & Current -- Perceptions

Stray voltage does not really exist! Simply stated, the phenomena is due to 60 Hz time-varying stray currents traveling in the earth or along a conductive path (i.e., wires, metal pipes and conduits, water, organic materials, cows, humans, etc.) back to the source transformer. Contact with stray currents can generate physiological sensations (i.e., tingling, shaking). One feels the 60 Hz time-varying current passing through the body: humans have an impedance of 1000 ohms across the body and cows 500 ohms (stray voltage can also be an issue for framers). According to Ohm's Law Voltage **(V)** = Current (**I**) x Resistance (**R**)**.** So, a 60 Hz time-varying current **I** (in amps) will generate a potential difference known as voltage (**V**) across any conductive object with a resistance **R** (in ohms) as the current **I** (in amps) passes through the conductive object.

There are three basic classifications for shocks from time-varying stray currents: perception and secondary shocks (which are annoying but not harmful) and primary shocks (which are very dangerous and potentially lethal). A safe perception shock (tingling response) for most men and women is 1.0 milliamps (mA) and 0.65 mA, respectively. Secondary shocks invoke involuntary muscle responses (shaking) that are very annoying and possibly painful. However, primary shocks begin at the *let-go current* where 99.5 % of all subjects can still voluntarily *let-go* of an energized conductor: 9.0 mA for men and 6.0 mA for women. Unfortunately, beyond the *let-go current* threshold, a victim's heart may be shocked into ventricular fibrillation resulting in imminent death if not medically treated (defibrillated) within 4-6 minutes. The National Electrical Safety Code (N.E.S.C.) specifies 5 mA as the maximum allowable *short-circuit current* from vehicles, trucks, and equipment due to electromagnetic and electrostatic induction under transmission lines. And the American National Standard Institute (ANSI) allows up to 0.5 mA leakage current from portable household appliances and 0.75 mA for fixed appliances.

Multi-Grounded Neutral (MGN) -- Myriad Of Ground Paths

In the multi-grounded neutral (MGN) distribution system supplied by the Herbertsville Substation, the primary neutral conductor is connected to earth by down-grounds and ground rods at frequent intervals (4 to 9 time per mile), bonded to surge-arrester ground leads, transformer neutrals, and all noncurrent-carrying parts (transformer tanks, guy wires) including the secondary neutral conductor and all other grounds (CATV, Telephone, etc.). Grounding the primary and secondary neutral is necessary to control over-voltages, ground fault protection and to ensure safety for the line crews. According to IEEE-C62.92.4-1991, section 4.4, *"A disadvantage to this practice is the occasional occurrence of abnormally high neutral-to-earth voltage (stray voltages) on the secondary system emanating from the primary neutral."* The problem is very complex since the entire neighborhood is electrically bonded together as follows (see Diagrams 1 - 4 on page 5): the primary neutrals are bonded to the secondary neutrals and ground wires on the poles, the service lateral neutrals are bonded in the disconnect switch/panel of each home at the neutral-ground bus that is also bonded (by N.E.C. and local codes) to the water pipe, ground rod, CATV and telephone cables. This myriad of primary/secondary neutral interconnectivity occurs between neighboring distribution circuits, so there are multiple return paths for both primary and secondary return currents.

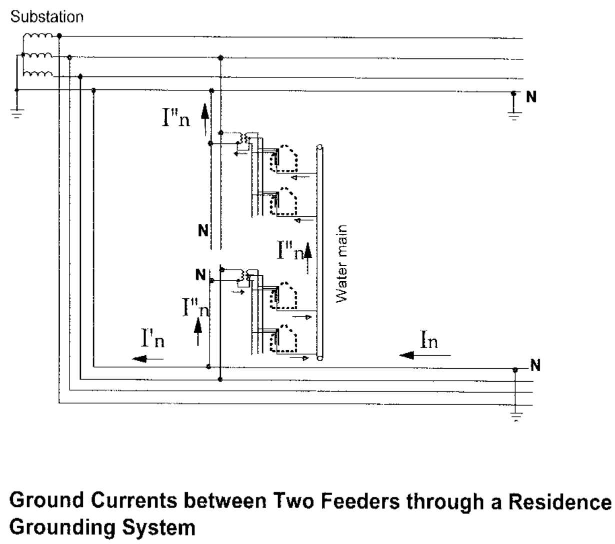


Diagram 1 – Circulating Neutral/Plumbing Currents

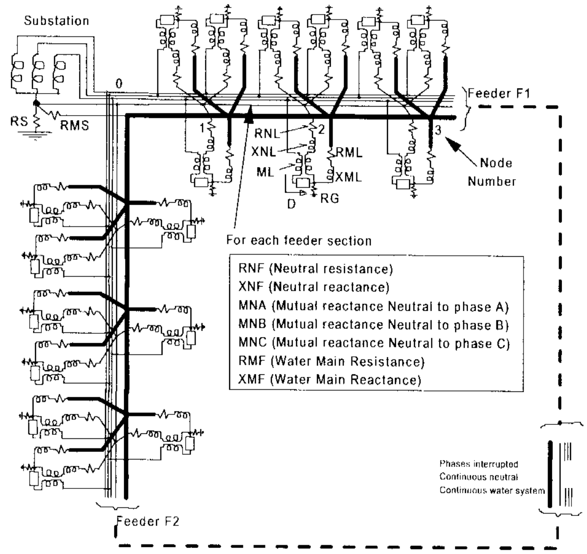


Diagram 2 – Neighborhood Impedance Model

In homes and neighborhoods, circulating secondary neutral currents (know as plumbing and net currents) generate localized stray currents and magnetic field problems on the service laterals, electrical panels, home wiring and water pipes between homes and/or streets (see Diagrams 1, 3 & 4). These problems are simple to test, usually caused by N.E.C. violations within one or several residences that can be mitigated by applying several known and tested solutions. *Unfortunately, the stray current problems in the neighborhoods adjacent to the Herbertsville substation are very complex and can only be solved by applying a system wide solution.*

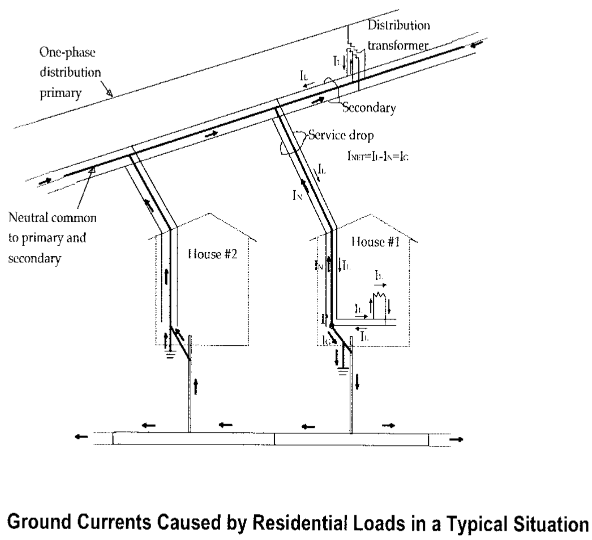


Diagram 3 – Circulating Neutral/Plumbing Currents

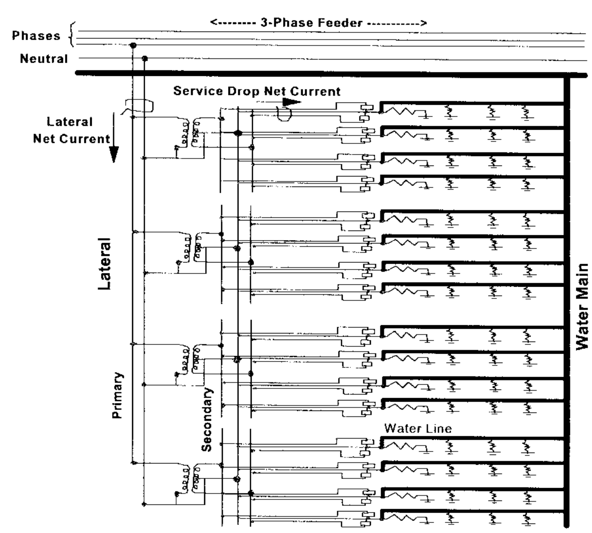


Diagram 4 – Neighborhood Service Lateral

Typical Substation & Distribution System

Simply stated, in a typical well-balanced distribution system (less than 10% unbalanced phases), the primary neutral currents from the distribution transformers return to the substation via two paths: low-impedance, properly sized, primary neutral conductors and the multi-grounded neutral (MGN) system that injects primary currents into earth (assuming low soil resistivity and/or high water table) which in turn flow via conducting earth channels (i.e., adjacent to water mains or sewers, in underground streams and water tables, between layers of slate, etc.) back to the substation ground grid. If the soil has high resistance around the substation (this is the case at the Herbertsville substation and adjacent neighborhoods according to the NJGS report), then the earth currents must return through the MGN down-grounds incrementally adding current pole by pole to the neutral conductors, thereby increasing the neutral-to-earth voltage (NEV) and the earth-to-earth voltage in the areas around the substation and neighborhood as shown in *Figure #3, Herbertsville Substation & Vicinity Recorded Neutral & Earth Voltages* and *Figure #5, Neighborhood Neutral-To-Earth (NEV) Voltages & Harmonics*.

Line 82 Primary Neutral Currents

Primary neutral currents measured at selected locations and circuits are shown in *Figure #4, Neighborhood Circuits Recorded Neutral Currents.* The primary neutral of Line 82 had 56 amps at the riser pole and only 29.5 amps (13 + 16.5 = 29.5) at the intersections of Driscol Drive with Spiral Drive and McArthur Drive. Where did the additional 26.5 amps come from? The larger customer load on Line 82 is north and west of the Driscol area and a portion of the primary neutral return current must be returning as earth currents. Examining the magnetic field harmonic spectrum data in *Figure #5, Neighborhood Neutral-To-Earth (NEV) Voltages & Harmonics* may elucidate this concept. Third harmonic currents returning up through the MGN down-grounds generate higher 3rd harmonic magnetic emissions moving south on Spiral Drive from Burnt Tavern Road to the substation. Why is this Line 82 current? Look at *Figure #2, Herbertsville Substation & Vicinity Recorded Neutral, Ground & Net Currents,* the net pole Riser 82 current is only 5.5 amps (this is the current not returning via Riser 82 neutrals and grounds). So, nearly all 26.5 amps (the balance of 56 amps – 29.6 amps) is from the larger customer load of Line 82 west of the Driscol area. These returning earth currents are migrating up the down-grounds and raising the Neutral-to-Earth Voltage (NEV) and the Earth-to-Earth voltage in the neighborhood adjacent to the substation. Remember, the primary neutral return current is a sum of the harmonic (3rd,5th, 7th, 9th, 11th, 13th, 15th, etc.) components, especially the triplen harmonics, which are due to the zero-sequence currents of the unbalanced phases. *Therefore, decreasing the harmonic content on the primary neutrals (not an easy task) will concurrently reduce the neutral-to-earth voltage (NEV) on the down-grounds, substation grid and earth-to-earth voltages around the substation and adjacent neighborhood.*

Line 80 & 80 Primary Neutral Currents

According to the data a significant proportion of the primary neutral current for Lines 80 and 81 returns to the Bank #2 transformer via the substation ground grid and grounding conductors. The switchgear ground wires (four total) of Bank #2 sum to 26 amps – this current returns to the Xo busing of the transformer via a new 500 MCM jumper (recommended by VitaTech with negligible impact) as shown in *Figure #2, Herbertsville Substation & Vicinity Recorded Neutral, Ground & Net Currents*. Another 16.7 amps returns by the ground grid, summing the total to 42.7 amps that returns directly to the 20 MVA transformer wye. For risers 80 and 81, the combined net pole current was 33 amps (13 + 20 = 33) with 9.7 amps (42.7 – 33 = 9.7) returning by another path (i.e., either neutrals on Lines 82 or 81). For Lines 80 and 81, a significant proportion of primary neutral current returns via the earth and other circuits (Lines 82 and 83) to the substation grid – not very good! This is the primary reason the substation grid-to-earth voltage is 9.3 V and earth-to-earth voltage 3.2 – 3.5 V in the adjacent Frede Park as shown in *Figure #3, Herbertsville Substation & Vicinity Recorded Neutral & Earth Voltages*. Magnetic flux density data recorded in milligauss (mG) on the ground inside the substation shows elevated levels along the south fence in Figures #6, #7 and #8. Figure #7 was included to verify higher levels were recorded on the ground rather than at 1-meter along the south fence. Earth currents from Lines 80 and 81 appear to return on the south side of the grounding grid because of the elevated magnetic emissions, which is bonded to the substation fence.

Line 83 Primary Neutral Currents
The Line 83 primary neutral currents is 22.5 amps at the riser pole, along the east service road, and south on Oak Knoll Drive until the intersection of Taft Avenue and Hoover Drive where 11 amps suddenly diverts north down Polk Drive as shown in *Figure #4, Neighborhood Circuits Recorded Neutral Currents*. The Riser 83 net pole current is 11.5 amps as shown in *Figure #2, Herbertsville Substation & Vicinity Recorded Neutral, Ground & Net Currents,* which indicates 11.5 amps of the 22.5 amps of primary neutral current is probably from Lines 80 and 81. The primary neutral current is 24 amps on Lines 80 and 81 west of Polk Drive, which share a single primary neutral, then the current divides where the Polk Drive neutral bonds to the Line 80 and 81 neutral: 12 amps continues east to the substation and 12 amps travels south down Polk Drive to Taft Avenue adding to the 11 amps from the Hoover Drive primary neutral (Route 88 and Jordan Drive areas) for a total of 23 amps, which is the total at Riser 83, along Oak Knowll and Taft Avenue. The Neutral-to-Earth Voltage (NEV) ranged from 5.7 – 6 V on the corner of Frede Drive and Oak Knoll Drive as shown in *Figure #3, Herbertsville Substation & Vicinity Recorded Neutral & Earth Voltages*. The additional primary neutral current is responsible for the elevated Neutral-to-Earth Voltages (NEV) at the Frede and Oak Knoll intersection. Primary neutral currents from Lines 80 and 81 are returning to the substation via the Polk Drive, Taft, Oak Knoll neutrals of Line 83. Needless to say, this clearly demonstrates the complexity of assessing stray current problems associated with return primary neutral and earth currents.

Neutral-To-Earth Voltages On Long Lines
The primary neutral-to-earth voltage on a long distribution line moves asymptotically towards zero – this means there is a minimum point where the neutral-to-earth currents change direction from entering the earth to returning from the earth.

Final Assessment & Recommendations
After performing a thorough site survey and assessment of the recorded data (neutral-to-earth voltages, earth-to-earth voltages, net pole/phase currents, ground and primary neutral currents, magnetic harmonics and magnetic flux density emissions), the following three issues contribute to the stray current (i.e., stray voltage) problems at the Herbertsville substation and four distribution lines 80, 81, 82 and 83:

1. Primary neutrals on Lines 80, 81, 82 and 83 not sized to accommodate soil and exceptional Summer 2002 drought conditions.
2. Poor soil conditions and low water table (saturation zone) at the Herbertsville substation and four distribution areas – impedes earth return currents traveling

back to substation. Soil resistivity increased by a factor of 2-3 during the summer of 2002 drought: soil resistivity during normal summers with adequate rain probably ranged from 600 – 1200 ohm-meters, then increased to 2,000 to 3,000 ohm-meters, if not higher, during drought.

3. Unbalanced phases exceeding 10% on Lines 80, 81, 82 and 83 during average load conditions -- could approach 20-25% during summer peak loads.

VitaTech recommends the following to mitigate the "stray voltage" problem in the Brick neighborhood and Herbertsville Substation:

1. Oversize primary neutrals on Lines 80, 81, 82 and 83 as specified in *Figure #12, Recommended Upgrade To Primary Neutrals* to match the size and impedance of the 397AA phase conductors. A total of 37,600 feet (7.12 miles) of upgraded 397AA primary neutrals are recommended to mitigate the stray voltage problem and achieve a neutral-to-earth voltage of 4-5 volts during summer months on the substation grid and down-grounds of the adjacent neighborhoods during peak summer loads. Specific routes and circuit length details for the recommended upgraded primary neutrals are provided in Figure #12; however, selected lateral circuits may also require upgraded 397AA neutrals to achieve the 4-5 volt summer performance objective including: Azalea Drive, Truman Drive, Harding Drive, Roosevelt Drive and Old Squan Drive.
2. No additional ground rods, mats or plates are recommended for the substation ground grid; however, the substation ground plane should be expanded to the extents of the new fence line with additional grounds bonded from the grid to the fence, where needed. (Note: this will have no adverse effect on stray voltage.)
3. Balance the phases on Lines 80, 81, 82 and 83 to within 10% (as measured by the SCADA equipment at the substation) during average loads (20-25%) and no more than 15% during peak summer loads to minimize zero-sequence currents.

Best Regards,

Louis S. Vitale
President & Chief Engineer
VitaTech Engineering, LLC

Attachments: Appendix – JCP&L's Herbertsville – Neutral-to Earth (NEV) Investigation
Figures #1 - #12

Appendix

JCP&L's Herbertsville – Neutral-to-Earth (NEV) Investigation

- Initial Complaint investigated by our Trouble Department – July 22, 2002
- Engineering Department contacted for follow-up – July 23, 2002
- Standard troubleshooting procedure followed
- Two breaks in neutral identified were repaired
- Reconductored neutral within development (neutral-to-earth voltage levels went from approx. 10V to 5V)
- Installed down grounds in development brought levels down to ~4V
- Re-crimped all transformer connections to down grounds
- Used insulated #2 cooper wire as jumper to quick test the substation grid integrity
- Herbertsville Substation is fed with two transmission lines @34.5KV- Isolated transmission feeds
- Installed additional down grounds around the substation area (down the easement)
- Jumpered out splices that looked suspect
- Drove additional ground rods (approximately 40ft deep) in area (neutral-to-earth voltage levels went from approx. 10V to 8V)
- Contacted Cable and Telco to involve them in the trouble shooting efforts.
    - All isolation tests performed with the other utilities have proven inconclusive as the effects of the multi bonded neutral system is cumulative.
- Contacted New Jersey Natural Gas to inquire about the cathodic protection system they use for metal pipes. We were told all pipes in area are poly.
- Contacted State of New Jersey, department of Environmental Protection for geological survey. Survey revealed high resistivity readings in the area.
- Off loaded Bank #1 which was the source of the circuits involving the neutral-to-earth voltage complaints. All connection form riser to XO bushing on transformer were checked.
- Ground Grid Tests were performed at substation.
- Offloaded all circuits fed from the Herbertsville Substation effects were cumulative. The results did indicate that a reduction in load would relieve the neutral-to-earth voltage levels.
- Further balancing of circuits is being recommended, although circuits are within operating parameters.

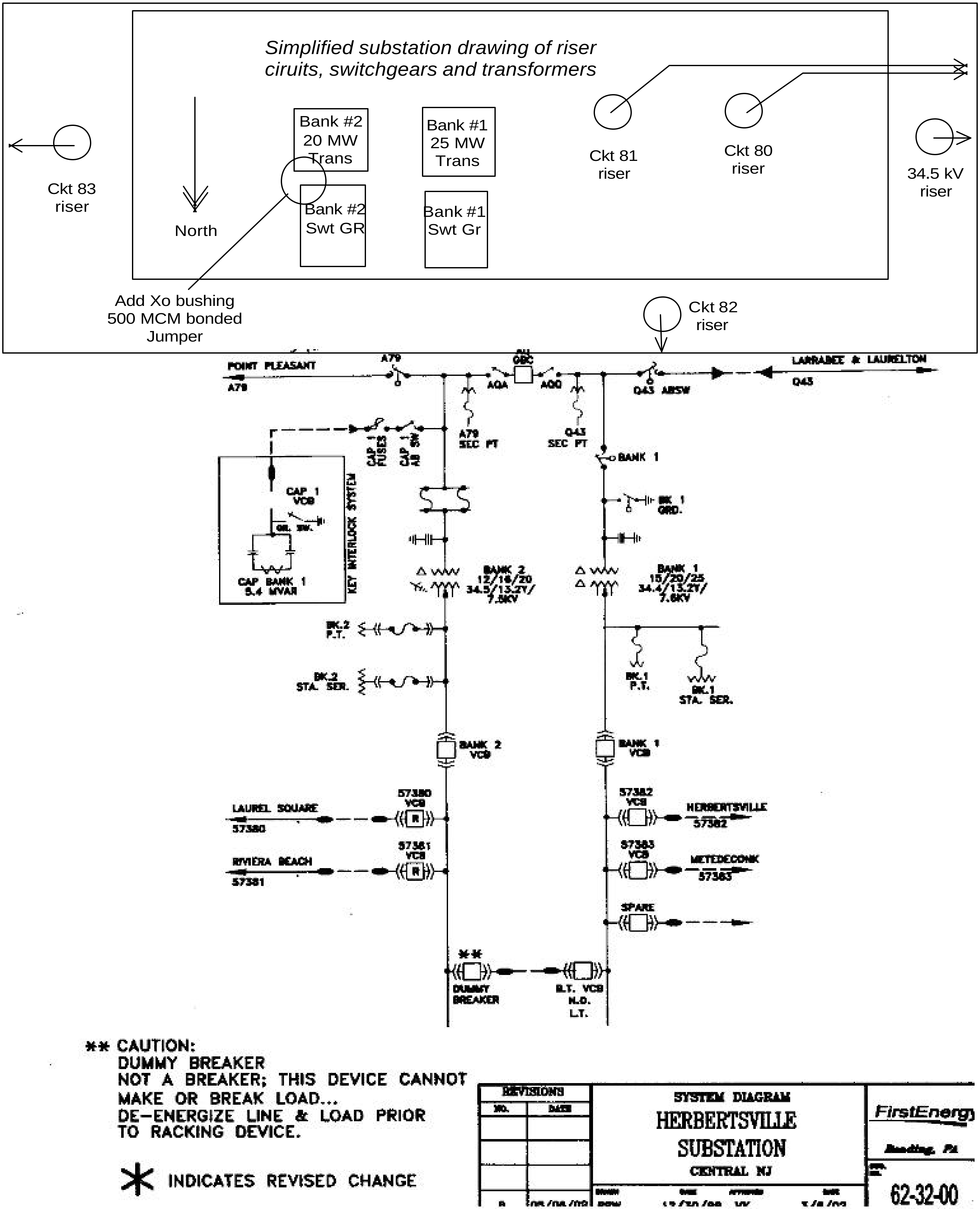


Figure #1, Herbertsville Substation Single Line Diagram

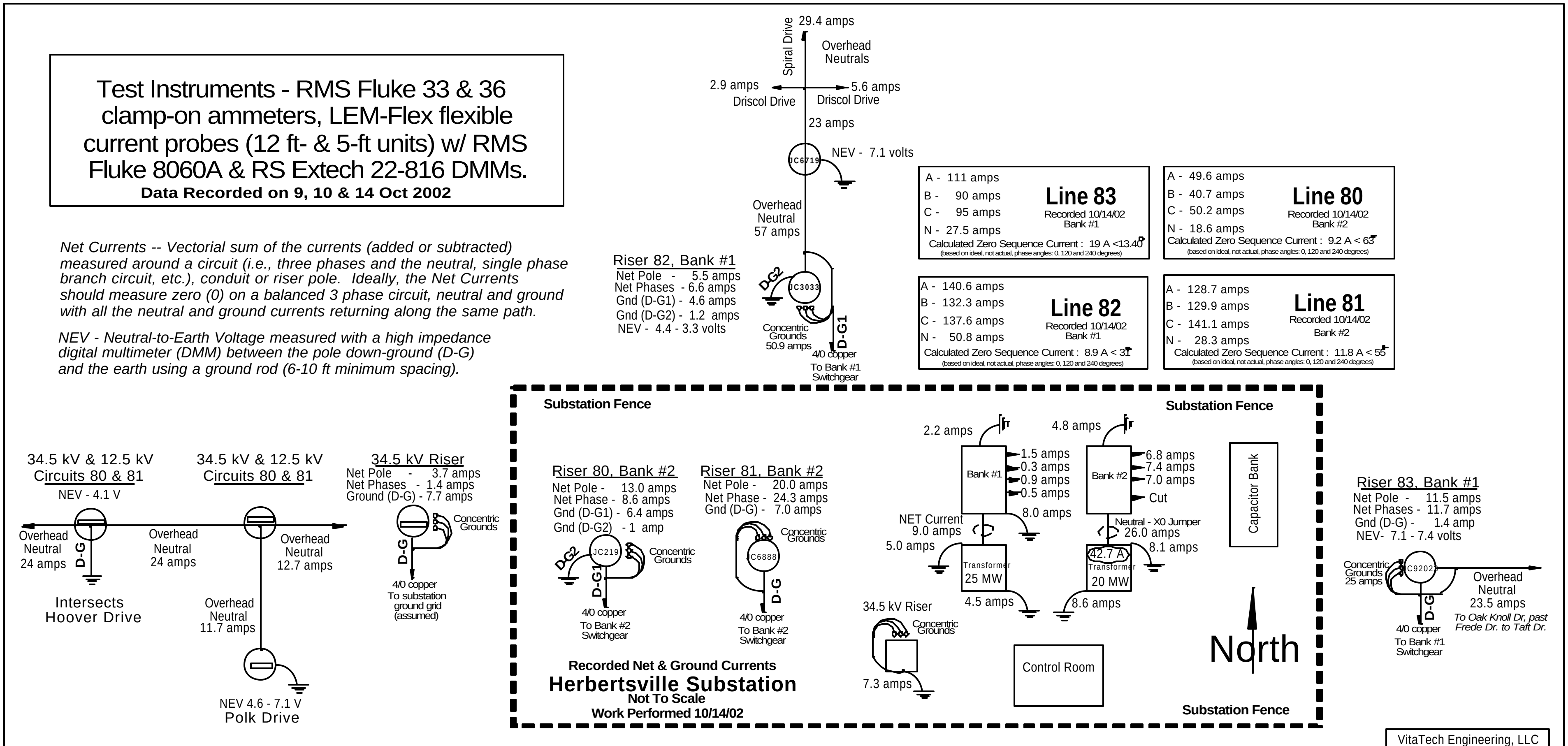


Figure #2, Herbertsville Substation & Vicinity Recorded Neutral, Ground & Net Currents

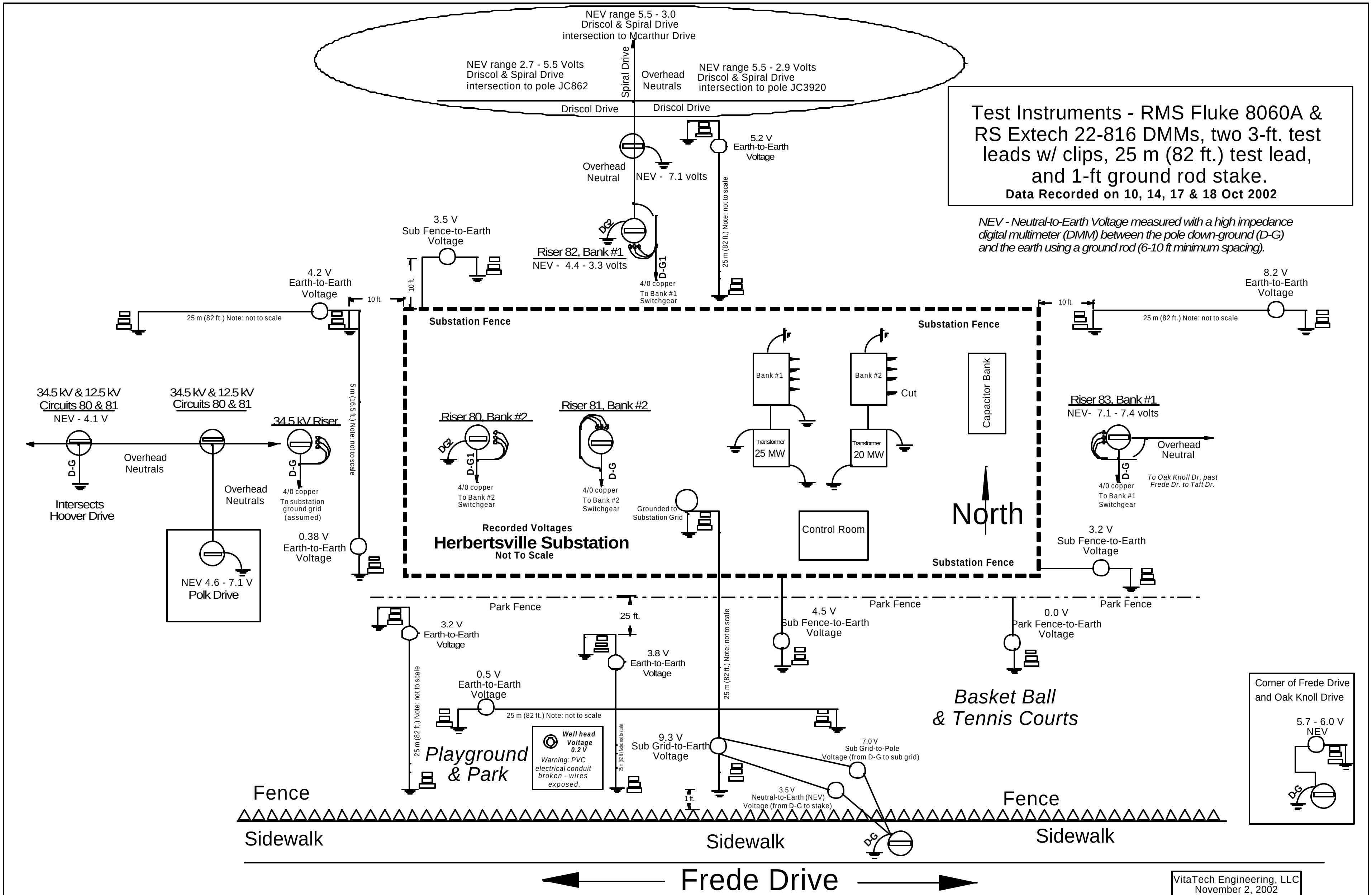


Figure #3, Herbertsville Substation & Vicinity Recorded Neutral & Earth Voltages

Figure #4, Neighborhood Circuits Recorded Neutral Currents

Only Primary & Branch Circuits Of Interest Are Shown

Test Instruments - RMS Fluke 33 & 36 clamp-on ammeters, LEM-Flex flexible current probes (12 ft- & 5-ft units) w/ RMS Fluke 8060A & RS Extech 22-816 DMMs.
Data Recorded by Line Crews on 14 & 18 Oct 2002

Four Primary & Branch 12.5 kV Circuits Color Chart

- Circuit 80 - Bank #2 (Primary Circuit - ABC) Solid Blue
- Circuit 80 - Bank #2 (Branch Circuit - Mix) Dotted Blue
- Circuit 81 - Bank #2 (Primary Circuit - ABC) Solid Green
- Circuit 81 - Bank #2 (Branch Circuits - mix) Dotted Green
- Circuit 82 - Bank #1 (Primary Circuit - ABC) Solid Red
- Circuit 82 - Bank #1 (Branch Circuits - mix) Dotted Red
- Circuit 83 - Bank #1 (Primary Circuit - ABC) Solid Orange
- Circuit 83 - Bank #1 (Branch Circuits - mix) Dotted Orange
- Street Continuation Without Circuits/Neutral Dotted Black

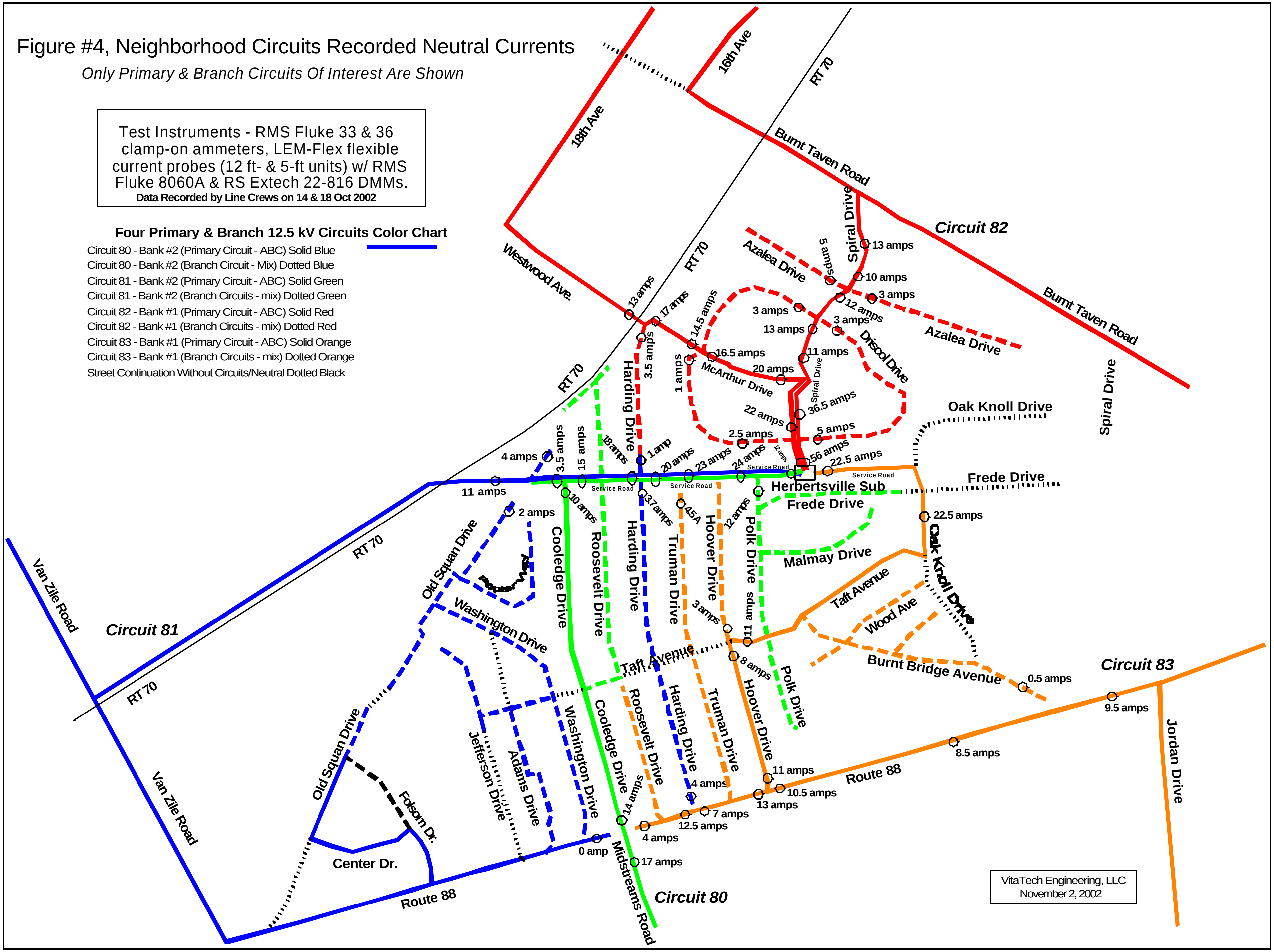
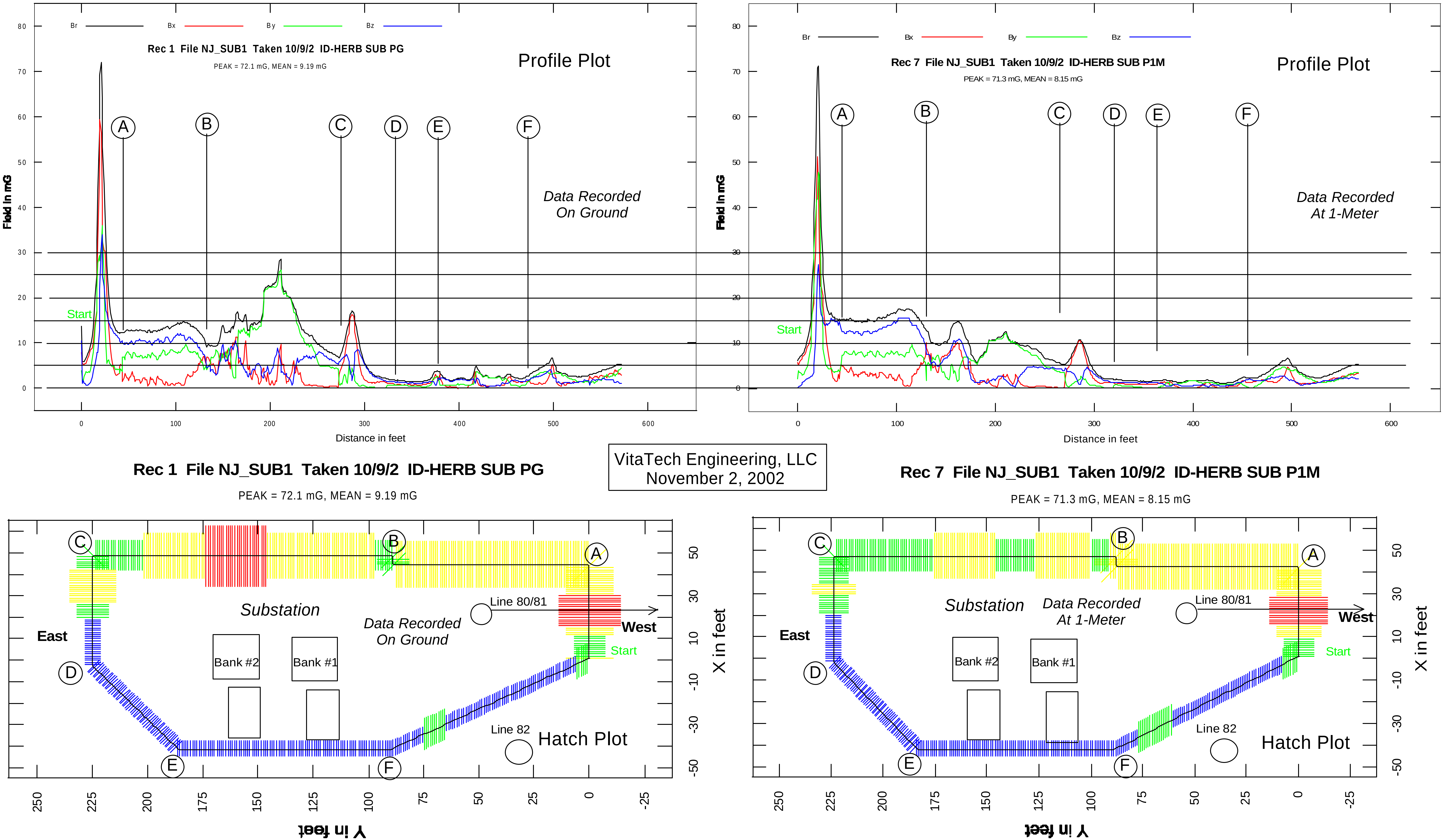


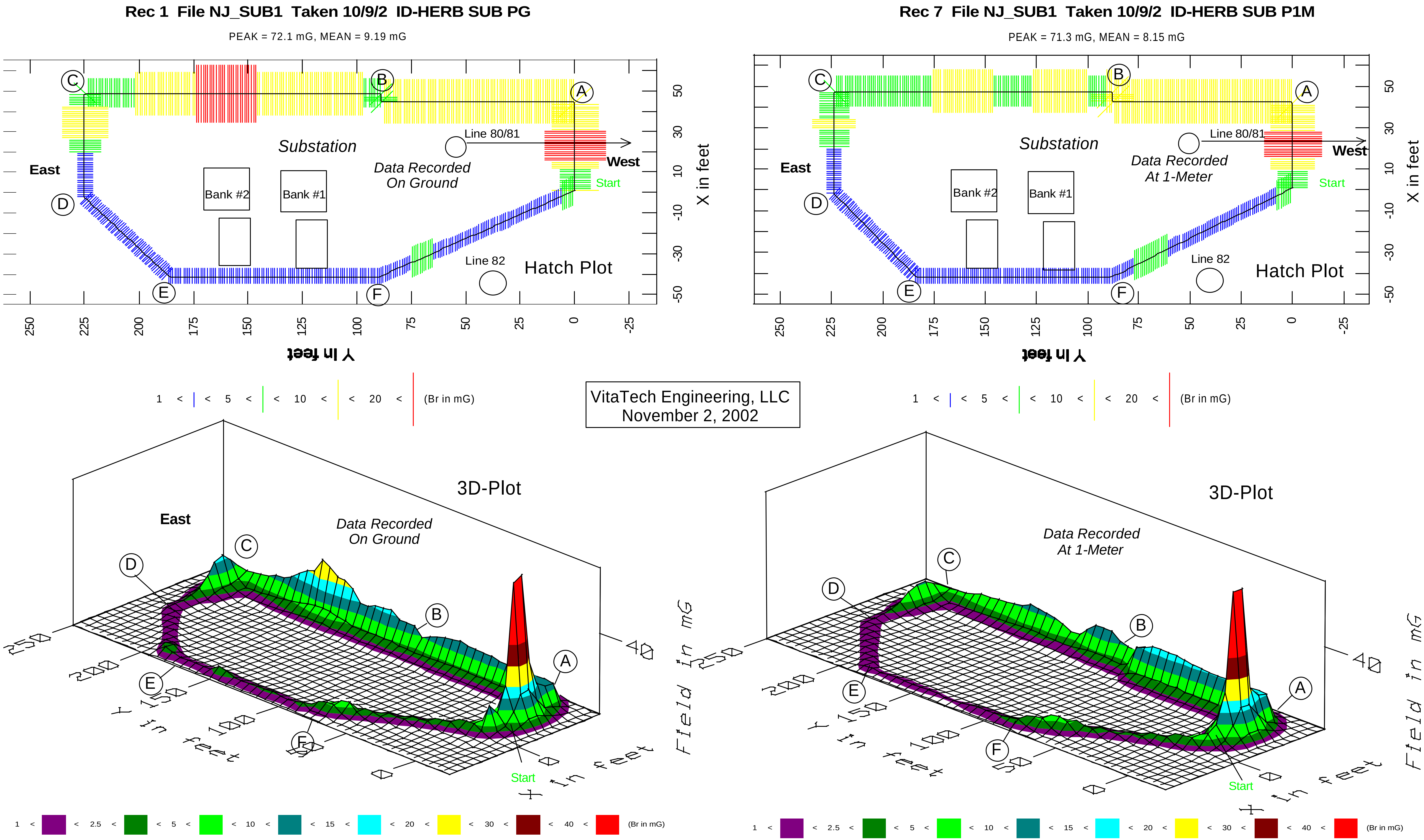
Figure #5, Neighborhood Neutral-To-Earth (NEV) Voltages & Harmonics
NEV (Neutral-To-Earth Voltages in Red) Recorded 10 & 16 October 2002
(Test Instruments - RMS Fluke 8060A & RS Extech 22-816 DMMs, two 3-ft. test leads w/clamps and 1-ft. ground rod)
Magnetic Field Harmonic Spectrum (in Blue) Recorded 17 October 2002
(Test Instruments - PMM EHP-50A electric & magnetic field probe set at 5 - 200 Hz bandwidth with PMM 8053 survey meter & data logger)
Example of harmonic output in milligauss (mG) - see Driscol Drive.
Notes: NEV - Neutral-To-Earth Voltage (in Red) is measured with a high impedance digital multimeter (DMM) between the pole down-ground (D-G) and the earth using a 1-ft. ground rod with 6-10 ft. minimum spacing (leads & clamps).
Magnetic Field Harmonic Spectrum (in Blue) shows the magnitude in milligauss (mG) of the 60 Hz fundamental and 180 Hz third harmonic measured 10 -15 ft. from the overhead circuits.
VitaTech Engineering, LLC
November 2, 2002
0.2 V 16th Ave & Burnt Tavern Rd.
0.2 V 16th Ave & Montclair Dr. ST4920
1.4 V Spiral Ave JC3070
Harmonics in mG 60 Hz 1.2 mG 180 Hz 1.2 mG between caps
Harmonics in mG 60 Hz 0.1 mG 180 Hz 0.1 mG
Harmonics in mG 60 Hz 2.8 mG 180 Hz 4.2 mG
Harmonics in mG 60 Hz 2.2 mG 180 Hz 3.2 mG
Harmonics in mG 60 Hz 0.3 mG 180 Hz 1.2 mG
Harmonics in mG 60 Hz 0.2 mG 180 Hz 0.8 mG
Disconnect CATV cable & reroute to business drop
Harmonics in mG 60 Hz 4.2 mG 180 Hz 7.4 mG
Harmonics in mG 60 Hz 3.1 mG 180 Hz 9.7 mG
Harmonics in mG 60 Hz 1.4 mG 180 Hz 5.9 mG
Harmonics in mG 60 Hz 0.2 mG 180 Hz 3.3 mG
Harmonics in mG 60 Hz 0.5 mG 180 Hz 3.3 mG
Harmonics in mG 60 Hz 0.7 mG 180 Hz 2.8 mG
Harmonics in mG 60 Hz 0.7 mG 180 Hz 5.8 mG
Harmonics in mG 60 Hz 1.6 mG 180 Hz 5.6 mG
Harmonics in mG 60 Hz 0.5 mG 180 Hz 2.1 mG
Harmonics in mG 60 Hz 0.8 mG 180 Hz 3.1 mG
Harmonics in mG 60 Hz 4.0 mG 180 Hz 12.8 mG
Harmonics in mG 60 Hz 2.6 mG 180 Hz 10.5 mG
0.2 V BT1495
16.8 V Home CATV
7 V Sub gnd to pole BT4319
6.8 V 19 Frede Dr
0.8 V Oak Knoll Dr Gnd Rod
HERBERTSVILLE SUB
BAY BRIDGE VILLAGE
WARWICK ESTATES
57380 LINE
57383 LINE
0.4 V Washington Dr. & Rt 80 JC732BK
0.3 V Midstreams Rd. & Rt 80 JC3001
0.1 V Jordan Rd. & Princeton Ave.
0.1 V Jordan Rd & Carrol Fox Rd.
0.4 V Jordan Rd & Waters Edge BT2309BK
200.0
400.0 FT
Prepared by: 2363
Date Printed: 10/09/2002 @ 3:56PM



1 < | < 5 < | < 10 < | < 20 < | (Br in mG)

1 < | < 5 < | < 10 < | < 20 < | (Br in mG)

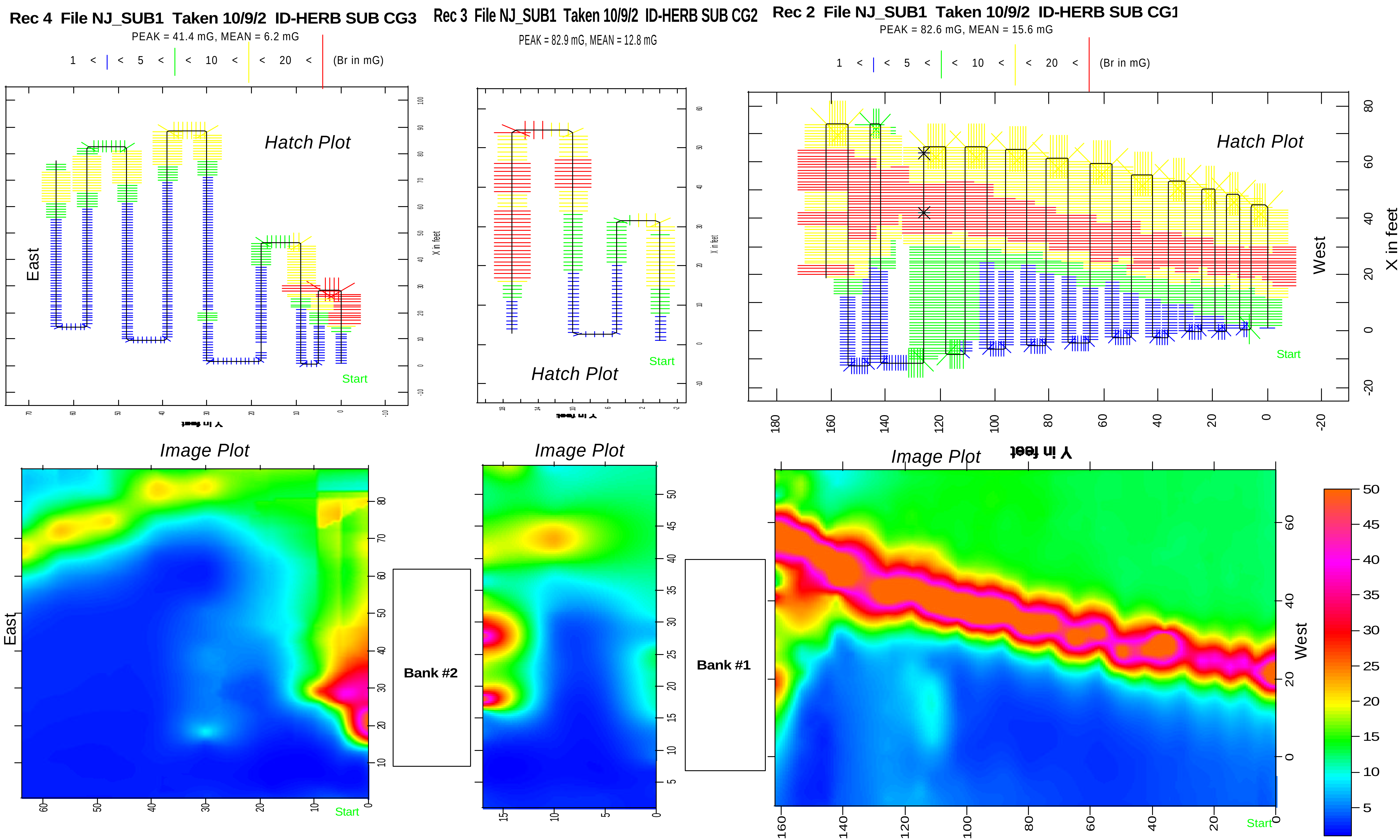
Figure #6, Herbertsville Substation Magnetic Flux Density Data
Perimeter Hatch & Profile Plots At Ground & 1-meter Levels



Rec 1 File NJ_SUB1 Taken 10/9/2 ID-HERB SUB PG
PEAK = 72.1 mG, MEAN = 9.19 mG, STD = 8.51 mG, MEDIAN = 7.44 mG

Figure #7 Herbertsville Substation Magnetic Flux Density Data
Perimeter Hatch & Contour Plots At Ground & 1-meter Levels

Rec 7 File NJ_SUB1 Taken 10/9/2 ID-HERB SUB P1M
PEAK = 71.3 mG, MEAN = 8.15 mG, STD = 8.01 mG, MEDIAN = 6.28 mG



Data Recorded On Ground

Figure #8, Interior Herbertsville Substation Magnetic Flux Density Data Contour (Mapped) Hatch & Image Plots At Ground Level

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Figure #9 - Driscol Drive Magnetic Flux Density Data October 10, 2002
Hatch, Profile & 3-D Plots Recorded at Ground Level

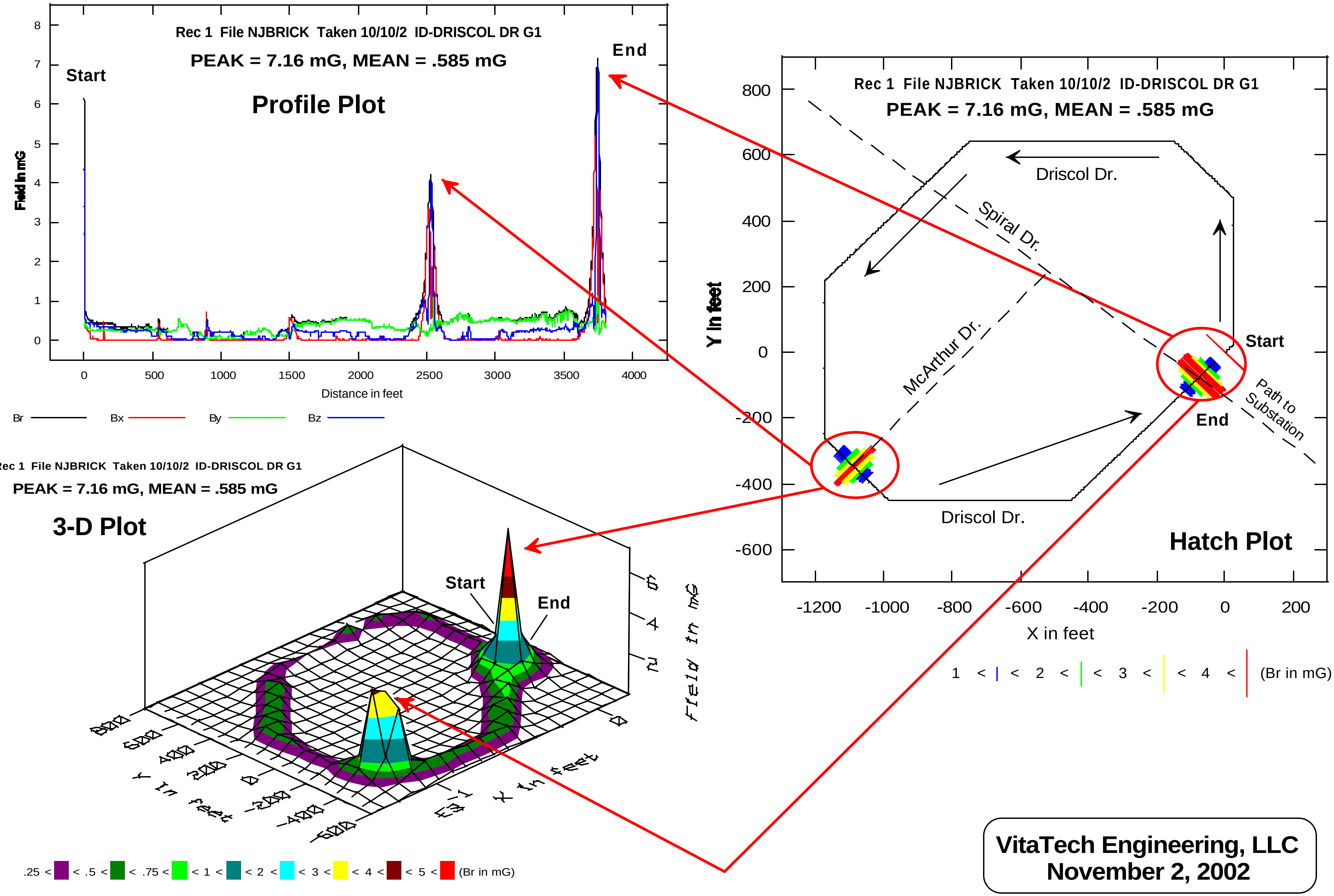
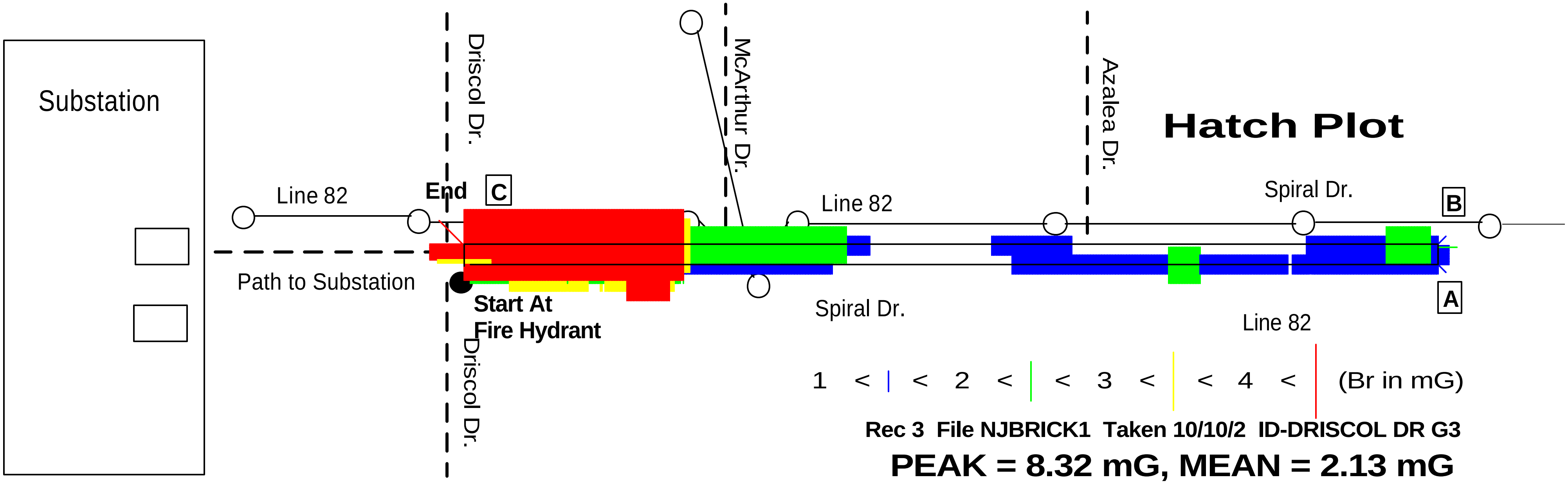


Figure #10- Spiral Drive Magnetic Flux Density Data, October 10, 2002
Hatch & Profile Plots Recorded at Ground Level



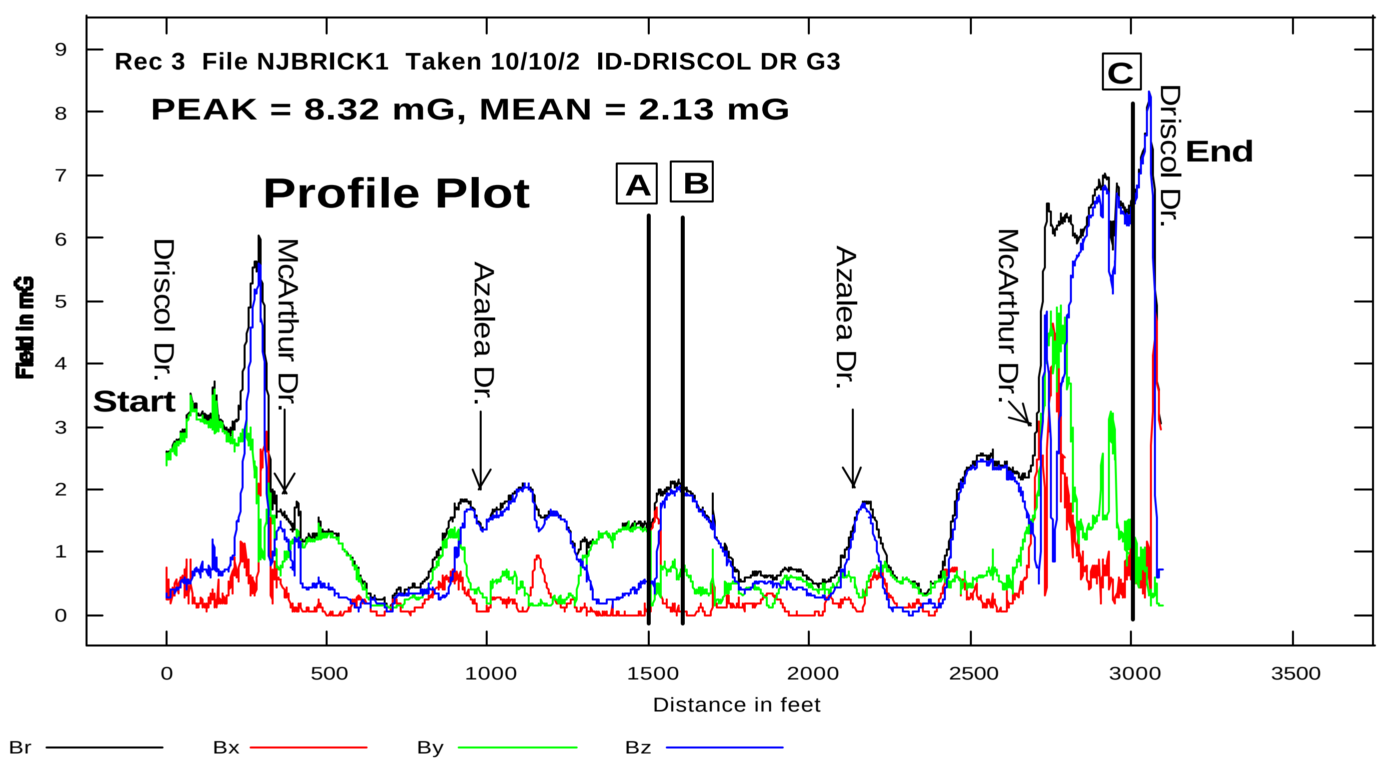


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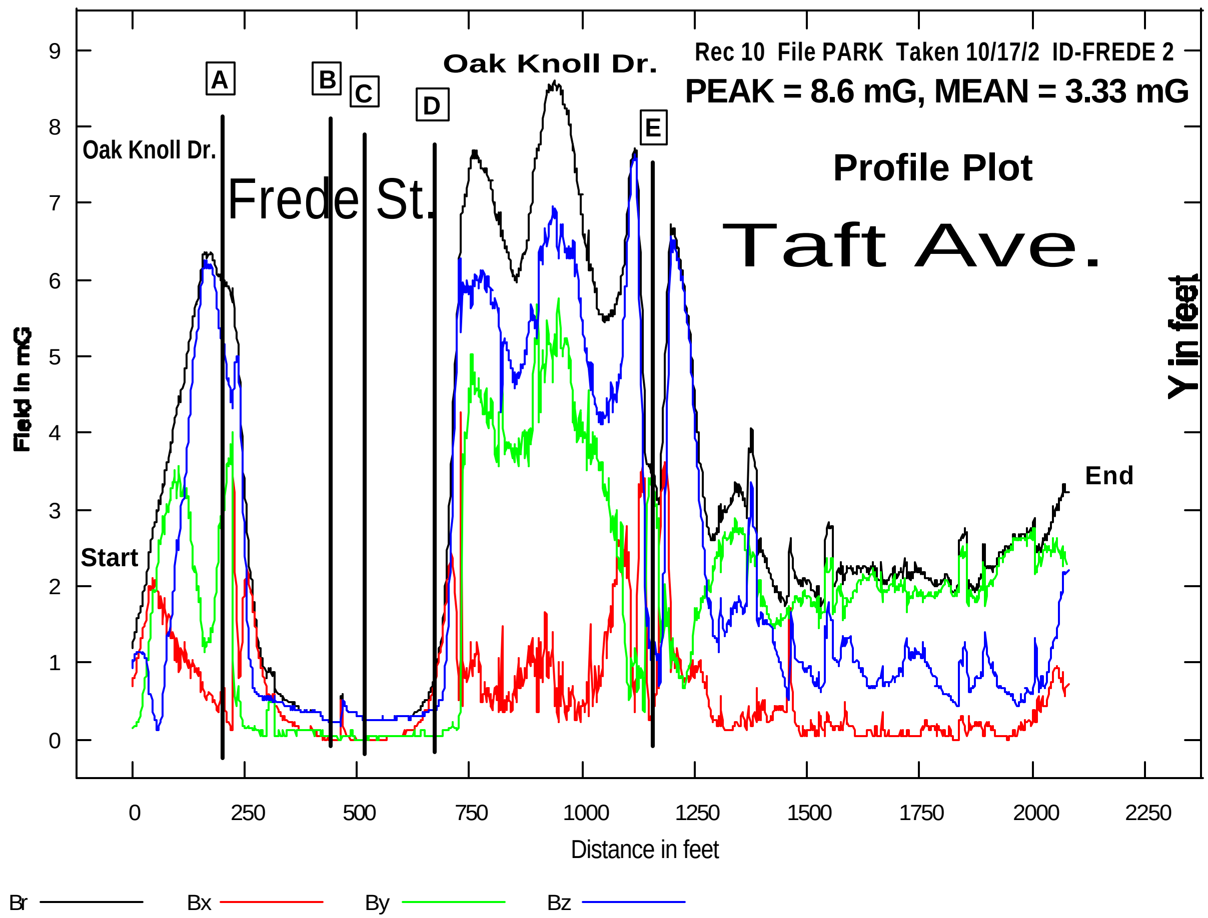
Figure #11 - Magnetic Flux Density Data Oak Knoll Dr. & Taft Ave., October 17, 2002
Hatch & Profile Plots Recorded at Ground Level



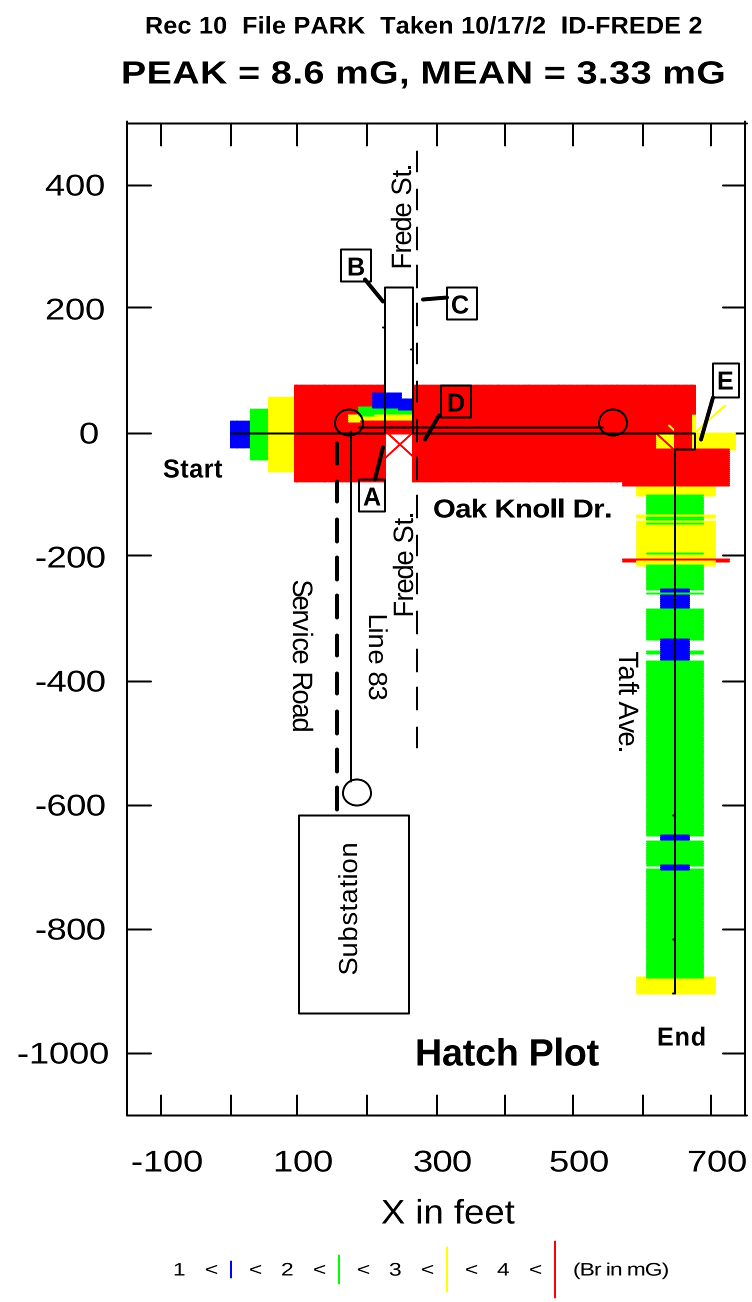


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Figure 12, Recommended Upgrade To Primary Neutrals